Modeling Livestock Farms Decisions Under Multivariate Selection Rules

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Abstract

The multivariate selection rule to modeling livestock farm is proposed to take into account the sample selection bias and to consider genetic and biological aspects. Based on multi-output and multi-input profit function with panel data, Heckman 2 step model is applied to consider sample selection bias, and the total size of herd, the unobserved farmer and animal heterogeneity are considered to consider genetic and biological aspects. For beef cattle and sheep farm, the price elasticity are significantly different by applying different selection rules. It can be useful to policy makers to evaluate the carbon reduction program using economic measure like tax or ETS on agriculture sector.

1. Introduction

Profit maximization on applied agricultural economics is theoretically stands on farmers behavior on economical factors. In livestock farm, the farmers have to decide how many animals they should breed, how many of them they should sell and when it would be the best timing for sale to maximize own profit. Therefore, the model for profit maximization is constituted on farmers' decisions on market condition through output and input prices. The farmers' behaviors depending on prices are also important to policy makers to implement efficient and effective policies because GHG emission regulation is dominated by the economic measures like tax, emission trading. Since livestock farm is one of largest source to emit methane(CH4) and CH4 emission which is fundamentally based on the number of animal, the response of farmers' behaviors are accurately investigated to improve policy efficiency to reduce GHG emission in livestock farm. For example, when CAP[1] was reformed in EU in 1992, breeders firstly

[1] CAP (Common Agriculture Policy) is the agricultural policy of the European Union. It implements a system of agricultural subsidies and other programs. It was introduced in 1962 and has undergone several changes since then. In 1992, the MacSharry reforms were created to limit rising production, while at the same time adjusting to the trend toward a more free agricultural market. The reforms reduced levels of support by 29% for cereals and 15% for beef.(Wikipedia)

focused on conforming to the individual quota of compensatory subsidies suckling cows. Next year, the change in the use of land space in order to be eligible for the grassland and crop subsidies became the main concerns to farmers. Moreover while the reform affected the breeding of males only a little, the breeding of heifers bose the main changes.[1]

The farmers' behaviors on policies not only depends on price, but also other numerous factors. Especially, in livestock farm, several problems should be considered in modeling with multi-output and multi-input profit function. First, the dependent variable of output supply and input demand function is often censored at zero which is considered as corner solution. Second, genetic and biological aspects are considered in model because the livestock is living asset. Third, the output supply is also influenced by unobserved individual heterogeneity like climate and soil conditions as well as specific breeding purposes depending on animal type.

The censoring problem leads to sample selection bias if unobserved random terms are correlated, and if the genetic or biological aspect and unobserved individual heterogeneity are not well included in estimation, this can mislead the results. In terms of livestock breeding, the corner solutions are common because some farmers breed only one type of animal, breed two and more types of animal together or introduce new or cease breeding certain type of animal. In terms of selling, there are also three cases: to sell from own animal asset, not to sell despite breeding and not to sell because of not breeding. Additionally, contrary to the assumption about input sources as necessary elements in profit function, there are a lot of non-use inputs by several reasons. For example, the concentrate feed is not always provided for animal, and the fertilizers are not always used by unknown reason, either. If corner solution is not correlated to observable or unobservable elements, the sample selection methodology is irrelevant. However if they are correlated, sample selection bias should be eliminated to get unbaised result. To eliminate the sample selection bias, the several econometric methodologies like the primal approach, dual approach, Tobit system estimated by generalized maximum entropy, maximum simulated likelihood procedures are suggested, and quasi-maximum likelihood estimator, GMM estimator, 2 step estimator and ML for multivariate sample selection model are also introduced as less efficient alternatives.[2] SEO and Mendelshon(2007) also applied three econometric models to examine which species farmers choose: a primary choice multinomial logit, an optimal portfolio multinomial logit and a demand system multivariate probit. The primary animal model examines the choice of the single species that earn the greatest net revenue on the farm. The optimal portfolio model examines all possible combinations of animals that farmers can choose. The demand system model examines the probability that a farmer will choose a particular species.[3]

The genetic and biological problem can be considered in three aspects. The first is fertility and mortality which affect the total size of the herd. The second is different breeding purposes depending on the type of animals. The third is the continuous reproduction and growth. The three factors look similar but each term is differently considered in model. A change of herd size can be an indicator to detect the fertility and mortality on each farm. Each farm tries to improve animal's health and genetic conditions. If animals get sick or die before reaching a certain level, they lose the economic market value. According to Goyache(2003), genetically, the selection to improve calf survival rates at weaning would lead to an improvement in calf viability at all earlier ages. Since the first economically important period in suckling cow production systems is the weaning time, sire evaluation for calf survival at weaning would be an interesting undertaking in beef cattle. The estimation of breeding values to select sires to a correlated response to improve the maternal ability for calf survival would not be justified[4] The different breeding purposes depending on the type of animals lead to different levels of profit maximization. For example, on beef cattle farm, the response to market price is different by age and sex of the animal because male calf mainly goes to meat market and female calf and cow are raised more for reproduction. The different purposes of the breeding become more complex under each farmer's unobserved individual heterogeneity.Thus, if the difference of animal type is not considered, the result may be overestimated to a certain type of animal, and underestimated to another type. To take into account this kind of unobserved individual heterogeneity, Marsh(2003) divided beef providing farms slaughter farm which provide mainly feedlot steers and heifers and feeder farms which mainly breeding cow to provide calves because demand and supply curve may be different by different types of farms.[5]Lacroix and Thomas(2011) dealt with the effect of unobserved components which are farmer specific(soil or technology), period dependent(climate, pest) to choose the land portfolio for several crops in crop farm.[6] In terms of reproduction and growth, all animal is strongly correlated by age because animal is living creature to get old and reproduced.Therefore, a selection to sell of an animal at current influences future livestock asset. It leads to apply the multivariate selection rule instead of the single selection rule.

The objective of this research is to apply multivariate selection rule in modeling livestock farm to deal with problems as mentioned above. For the empirical application, all livestock farms are defined as multi-input and multi-output farm even if a farmer breeds only one species between sheep or cattle. Animals are categorized in four types by age and sex[2]. The output supply and input demand functions are derived from Normalized Quadratic Profit Function, where dependent variables of equations often

[2]animal is categorized by 4 type: young female, young male, old female, old male

censored to zero. To deal with data censoring, normally Type I Tobit is used to get unbiased results. If the data censoring, however, is more correlated with other explanatory variables such as fixed costs to work such as commuting costs that are more important in determining participation than hours of work in job market, the sample selection model(Type II Tobit) should be applied. In presenting paper, the change of the size of herd to take into account the fertility and mortality and individual variables to represent the different breeding purpose depending on farmer and animal type are added to explanatory to determine participation. Although the sample selection model is theoretically based on MLE, easily applicable Heckit 2 stage method(Heckit model) proposed by Heckman to correct sample selection bias is applied. The Heckit model is constituted by 2 separate regression, the main concept is the adding "Inverse Mills Ratio"[3] which is generated by probit to OLS equation as an explanatory variable.[7] Finally, IMR of each type of animal is included to another type of animal to extend to multivariate selection rule.

The results are the elasticity between price and selling quantity and the elasticity between subsidy and breeding quantity are significantly affected under multivariate selection rule, but not the same effect to all type of animal. The differences are shown by comparing the single selection rule and multivariate selection rule in paper. The contribution of this paper can be described as following. First, the multivariate selection rule is firstly applied in modeling livestock farm. Second, genetic and biological elements are considered to take into account fertility, heterogeneous breeding purpose of different animal type and reproduction. Third, climate disaster is considered. The climate disaster like drought or inundation is unexpected exogenous shock to animal farm. It is meaningful because the response of livestock farm to climate change is less studied than the contribution of livestock breeding to climate change. The reminder of this paper is organized as follow; chapter 2 provides the general descriptions of GHG emission of agriculture and animal farm. Section 3 presents the theoretical procedure to apply multivariate selection rule, chapter 4 describe data and variables definition. Chapter 5 presents results the price elasticity with different selection rules and effect of the climate accident, and chapter 6 is about conclusion and further consideration.

2. General Description about the GHG Emission in Agriculture

   (a) GHG Emission in Agriculture

   In whole world, agriculture land which can categorized to cropland, grassland and permanent crops occupies about 40-50% of the earth land surface. The GHG Emission from agriculture is estimated 5.1~6.1 GtCO2 equivalent in 2005 and it share 10~12% of total GHG emission. [8]This ratio seems to be low against

[3]IMR: the ratio of the probability density function to the cumulative distribution function

power plant or other heavy industry, but CH_4 emission is 3.3GtCO2e which occupies 50% of total CH_4 emission, and 2.8GtCO2e of N_2O emission occupies around 60% of total N_2O emission. In EU, emissions from EU agriculture caused by crop and livestock production activities is about 405 MtCO2eq or 10% of total European emissions. Nitrous oxide emissions (from fertilizer application and manure management) represent approximately 210 MtCO2eq, while methane emissions (from enteric fermentation, manure management, and rice cultivation) account for about 195 MtCO2eq. [8] In France, The agriculture is the third largest contributor of national GHG emission after transport and industry, and followed by housing. the emission from agriculture is 17.8 % (94.4MtCO2e) in 2010 of the 17.8% emission, 9.8% are due to N_2O, produced during biochemical nitrification and denitrification reactions, while 8.0% are related to CH_4 produced fermentation. French agriculture occupies 86.6% of France total N_2O emission and 68% of total French CH_4 emission.(excluding LULUCF). CO_2 emission from agriculture is negligible (less than 2% in France and 6% of cost share of farm). [9] The magnitude of abatement costs in agriculture relatively to other sectors determines both the social benefit and the effective reduction that can be expected from the implementation of a mitigation policy in this sector. [10]

(b) Main Sources and Expectation

The agriculture is main contributor to emit CH_4 and N_2O.In the total non-co2 emission from agriculture, N_2O from soil and CH_4 from enteric fermentation constitute the largest source, 38% and 32% of total, and the biomass burning, reproduction and manure management rank respectively 12%, 11%, 7%. N_2O emission farm soil mainly associated with N fertilizers and manure applied to soil and CH_4 emission from enteric fermentation due to livestock population, especially a combined stock of cattle and sheep equivalent to 60% of world totals. the GHG emission from ruminants account for one third of non-co2 emission. In the case of enteric fermentation, the global total emission is 2,071MtCO2e, about 40% of total CH_4 emission. CH_4 emission from fermentation is dominated by Cattle(55% of non-dairy, 19% of dairy), and buffalo(11%), sheep(7%) and goat(5%) follow. The emission form Annex I countries(developed countries) decreased 9% while increase 19% in non-annex countries during 2000yr-2011yr. Regionally, Asia and America are main contributors (respectively 37%, 33%)followed Africa(14%) and Europe(12%). Although the agriculture is main contributor of national emission inventory in Oceania, the share of total emission from agriculture is about 4%.

The more important thing beyond current emissions situation is that the GHG emissions from agriculture are increasing, especially the increase rate is higher in developing countries which are responsible 3 quarters of total GHG emission in agriculture sector. Since the population increasing through technological development, public policies and economic growth drive the agriculture sector emit more, GHG emissions from agriculture are expected to increase in future continuously even though management practice and emerging technologies may reduce the increasing rate. Especially in animal farm, growing demand for meat may induce further changes in land use and increased demand for animal feeds will encourage emitting more GHG emissions in animal farm. For example, the intensive production system to breed larger herd of beef cattle not only permits to increase GHG emissions faster than growth in grazing based system which may attenuate increasing rate but it is also emission increasing factor in terms of manure management. [8] FAO estimate N_2O emission in 2030 will increase 35%-60%, but change in feeding method and manure management will alleviated CH_4 emission to increase by 21% between 2005 and 2020.[11]

(c) The Policies To Reduce GHG emissions in Agriculture

To reduce non-co2 GHG emission, the numerous direct and indirect policies are implemented in agriculture and related sectors under EU and national level. FAO proposed the main policies such as improving forage quality and the overall efficiency of dietary nutrient use is an effective way of decreasing GHG emissions per unit of animal product in terms of animal farm. The several feed supplements have a potential to reduce enteric CH_4 emission from ruminants, although their long-term effect has not been well-established and some are toxic or may not be economically viable in developing countries. Additionally, the manure management practices have a significant potential for decreasing GHG emissions from manure storage and after application or deposition on soil. Since the interactions among individual components of livestock production systems are very complex, various condition must be checked when GHG mitigation practices are implemented in agricultural sector.[12]Additionally, adding certain oil or oilseed can be helpful to reduce CH_4 emission from enteric fermentation. and some kinds of additives such as tannins, yeast or vaccines is proposed to reduce CH_4 emissions. The longer-term management change and animal breeding means productivity increasing such as meat producing animals reach slaughter weight at a younger age, with reduced lifetime emission. However, this method is still needed more scientific research because of biological and ecological complications. The co-assess the environmental impacts and economic performances of French suckler-beef production systems based on commercial farm data. And with the main variables such as non renewable energy consumption, animal productivity, farm size and degree of specialization in beef production, the environment effect are estimated in animal farms. the large, diversified farms have a more negative environmental impact than the moderate-sized, specialized farms.The animal productivity performances decrease with increasing herd size, and inputs use is below-optimal in the most strongly diversified farms.[13] INRA also provided many analysis about GHG mitigation policies such as the intensive and self sufficient systems for low negative environmental impact, good economic results, and low sensitivity to price volatility.[14] Additionally, INRA analyzeed representative ten measures that could help to reduce GHG emission in agriculture. Of ten measure, 3 measures are related to livestock is helpful to reduce CH_4 and N_2O emission. Those three measures are using additive to reduce entericCH_4 emission, replace nutrient to reduce N in manure and install flaring system to reduce CH_4 related to manure storage. Additionally, INRA also studied that CH_4 by dairy cows can be reduced by 30% if vegetable oil with a high polyunsaturated fatty acids contents includes to feed. EU also measured GHG emission reduction policies at farm level, selected measures related to livestock are improvement of manure storage to reduce CH_4 and Ammonia which is precursor gas of N_2O", the manure spreading as fertilizer close to cropland and biogas to generate electricity by using slurry, residues and other plants. [9] Veysset et al(2014) also studied economical research such as a comparison of the group of farms with the lowest and highest GHG emissions per kg beef confirmed the correlations about Animal productivity performances decreasing with increasing herd size, and below-optimal inputs use. The result is that size and diversification bring economic and environmental economies of scale and scope in suckler-beef production systems.[15]The interest in increasing animal productivity is debated, because the reduction of CH_4 emissions for the animal is often offset by increased emissions of N_2O and CO_2 or other environmental impacts for the livestock production system. therefore, different techniques to reduceN_2O emissions are discussed and Limiting nitrogen mineral fertilizers to as little as strictly necessary is especially efficient.[16] In addition, particular attention is paid to increasing carbon storage in soils to partially offset emissions and organic farming can reduce GHG emission by 3% with including soil sequestration.[14]

3. Methodology

The production economics was begun to emerge as an integrated field that analyzed farm management and production issues from farming to and including marketing of agricultural products.[17] The theories of cost function and profit function linked with production function by duality well developed with various modeling assumption and econometric methodologies, the flexible functional form is popularly used for production analysis because it has advantage to have estimable relationship with relatively few prior restriction. There are numerous flexible functional form to apply the production economics and each flexible function has own advantage or disadvantage. For example, by comparing the performance of translog expenditure function to that of quadratic benefit function, quadratic parametrization perform better based on the fraction of monotonicity and curvature violations is founded.[18]

(a) Multi-input And Multi-output Profit Function

Consider price-taking farmer and this farmer breeds a type animals denoted A. Farmer has animal like "asset" and decide to sell how many animal to meat market. Let a= 1,2,...A denote each type of animal, U_a denote animal asset based on LU(Livestock Unit) which means a number of breeding animals,$\mathrm{p}_a$and r_a denote output animal price and subsidy rate (per LU) respectively, and $q_a$denote the ratio between selling animals and breeding animals for each year. Therefore, $U_a q_a$ implies the selling quantity of each animal, The input prices and quantities are denoted byw_k, x_k . k= 1,2,...K. the profit function is following.

$$= \sum U_a(\mathrm{p}_a q_a + r_a) - \sum \mathrm{x}_{ki} w_k \tag{1}$$

Farmers maximize their profit under the constraint on total land(L) which is considered by quasi fixed input. Each farmer chooses the optimal decision for profit maximization how many animal they breeding U_a (p,r,w,L), how many animal they sell q_a(p,r,w,L) and how much they input x_k (p,r,w,L). To the select functional form, as following the second order flexible functional form is usually used since 1980s for agricultural economics. In this model, symmetry normalized quadratic function is applied. normalized quadratic profit function is following

$$(p,w) = \mathrm{SS}_0 + \sum_{a=1}^{A}\mathrm{SS}_p p_a + \sum_{a=1}^{A}\mathrm{SS}_r r_a + \sum_{i=1}^{I-1}\mathrm{SS}_k w_k + \sum_{a=1}^{A}\sum_{a'=1}^{A}\mathrm{SS}_{pr} p_a r_{a'} + \sum_{a=1}^{A}\sum_{k=1}^{K-1}\mathrm{SS}_{pw} p_a w_k$$

$$+\sum_{a=1}^{A}\sum_{k=1}^{K-1}\mathrm{SS}_{rw} r_a w_k + \frac{1}{2}\sum_{a=1}^{A}\sum_{a'=1}^{A}\mathrm{SS}_{pp} p_a p_{a'} + \frac{1}{2}\sum_{a=1}^{A}\sum_{a'=1}^{A}\mathrm{SS}_{rr} r_a r_{a'} + \frac{1}{2}\sum_{k=1}^{K-1}\sum_{k'=1}^{K-1}\mathrm{SS}_{ww} w_k w_{k'} \tag{2}$$

where, all prices are normalized by w_K

Differentiating profit function with respect to output prices, subsidies and input prices

$$U_a q_a = Q_a = \frac{\partial \pi}{\partial p_a} = \mathrm{SS} + \sum_{a=1}^{A} \mathrm{SS}_{pr} r_a + \sum_{k=1}^{K-1} \mathrm{SS}_{pw} w_k + \sum_{a=1}^{A} \mathrm{SS}_{pp'} p_a \tag{3}$$

$$U_a = \frac{\partial \pi}{\partial r_a} = \mathrm{SS}_r + \sum_{a=1}^{A} \mathrm{SS}_{pr} p_a + \sum_{k=1}^{K-1} \mathrm{SS}_{rw} w_i + \sum_{a=1}^{A} \mathrm{SS}_{rr} r_a \tag{4}$$

$$x_k = \frac{\partial \pi}{\partial w_k} = \mathrm{SS}_k + \sum_{a=1}^{A} \mathrm{SS}_{pw} p_a + \sum_{a=1}^{A} \mathrm{SS}_{rw} r_a + \sum_{k=1}^{K-1} \mathrm{SS}_{ww} w_k \tag{5}$$

The output supply and input demand function are derived by differentiating profit function with respect to price, animal-specific subsidy and input price. One remarkable thing is that the function about breeding quantity is included to track the change of total size of herd to maximize profit. The breeding quantity is important because input demand relies on breeding quantity rather than selling quantity. Therefore, 2 output supply function to determine the animal selling and breeding quantity, and 1 input demand function in this model. The profit function should follow some property for well-behaved such as homogeneity of degree one in price, convexity in output prices, monotonicity and symmetry. The profit function easily get homogeneity by numerizing w_K because w_K is automatically computed under the property as the sum of price elasticity for input and output should be zero. The elasticity is calculated by price or subsidy rate by the ratio the price over the animal keeping and selling quantity.

(b) Sample Selection Bias and Corner Solution

The censoring problems are raised when the dependent variable is lost, but not data on the regressors. The leading example of censoring problem is the Tobit model which consider linear regression under normality. The Tobit model based on MLE is suggested by Tobin and Amemiya provided a formal proof.[19] In agriculture economics, the data censoring or truncation problems are easily detected. For example, through bi-variate sample-selection model and two-part model, differentiated effects of variables on probabilities and levels of consumption also suggest rejection of the Tobit system. Gender differences are present, and demographic variables are more important than income in determining consumption of cigarettes, beer, and wine.[20] In crop farm, the crop supply irregularly convert to zero caused by no land allocation to specific crop in specific year, and the reason of no land allocation is crop rotation as well as short-term changes in profitability.[6] In livestock farm, no breeding or no sale of a certain type of animal is censored. In a sheep farm, all farmers unexceptionally breed sheep. In a beef cattle category, all farmers also unexceptionally breed male calves. These 2 types of animal are the main resource to get revenue in each sheep and beef cattle farm. Thus, sample selection bias is not affected to decision on breeding of these types of animal. However, some farmers breed two and more types of animal together, introduce new animals or cease breeding a certain type of animal. If the decisions on breeding are correlated between animals or between times, the sample selection bias may exist. In terms of selling, there are also three cases: to sell from own animal asset, not to sell despite breeding and not to sell because of not breeding. The first and third cases are reasonable, farmers sell what they have, and do not sell what they do not have. Sometimes, farmers keep their animal not to sell to market because not-selling is economically or other non-economically better. For example, In sheep farm, even if many farmers breed cow and male calf beside sheep but in many cases, selling quantity of those type of animal as well as sheep is convert to zero. Tobit model to deal with censoring problem is described as following.

$$y_i = X_{iat}\beta + \varepsilon_i \tag{6}$$

y_i=y_i if y_i>0, y_i=0 otherwise
y_i: $U_a q_a$,U_a,$x_k$function of ith farmer
X_{iat} is a vector of explanatory variables of ith farmer to a type of animal at time t.

This is Type I Tobit model. If the censoring data in livestock farm is only related to explanatory variables in profit function, however, Type I Tobit as above can be a consistent method. However, the reasons can be different to determin $y_i$is zero or not, and how much of y_i. For example, in job market, the decision to participate job market is determined by not only dependent to wage level, but also other variables like education and distance related to wage. In the farm-level data inlivestock farm, the decisive variables to make the corner solutions cannot be limited to only prices and subsidies.. If the decisions on breeding or selling a centain type of animal is caused by another factors, Type I Tobit cannot be applied. In livestock farm, actually, the corner solutions which are detected frequently in U_a, $q_a$and x_k are not only caused from the economic reasons, but also the genetic and biological reasons. For those reason, Type I Tobit cannot be applied to analyze animal farm to deal with censoring data because the determinants for animal selling or breeding is not only limited in explanatory variables in profit function. The more generalized Tobit model based on MLE which is normally used to deal different explanatory variables to determine participation(y_0) and quantity(y_1), is named as bivariate sample selection model studied by Heckman[7] In animal farm, The sample selection model can be described as following.

$$y_{iat} = d_{iat} * y^*{}_{iat}(d_{iat} = I \mid d^*{}_{iat} > 0) \tag{7}$$

$$y^*{}_{iat} = X_{iat}\beta_a + \psi_{iat} \tag{8}$$

$$d^*{}_{iat} = Z_{iat}\delta_a + \omega_{iat} \tag{9}$$

The equation (8) and (9) denote an outcome and selection equation. y_{iat} denote dependent variable of each input demand function and X_{iat} is the vector of explanatory variables in outcome equation, and $d^*{}_{iat}$ is latent variable, and $Z_{iat}$is a vector of $X_{iat} + \vartheta$ (ϑ is selection indicators).ψ_{iat} &ω_{iat}means i.i.d. error term. $X_i$and Z_i are observable variables and estimate by maximizing the following average likelihood function[21].

$$L = \frac{1}{N}\sum\left\{d^*{}_i * ln\left[\int_{-Z_{iat}\delta_a}^{\infty} \phi_{\psi\omega}(y^*{}_{iat} - X_{iat}\beta_a, \psi)d\psi\right]\right\}$$

$$\left\{+(1 - d^*{}_i) * ln\left[\int\limits_{-Z_{iat}\delta_a}^{\infty}\int\limits_{-\infty}^{\infty} \phi_{\psi\omega}(\omega, \psi)d\omega d\psi\right]\right\} \tag{10}$$

In this equation, $\phi_{\psi\omega}$is PDF for bi-variate normal distribution. Therefore, this estimation relies on normality assumption. If $\phi_{\psi\omega}$=0, it means no selection bias. If $\phi_{\psi\omega}\neq$0, additional variables to selection equation impact to outcome equation.

To modeling livestock farm, the proxy to represent a genetic and biological aspect should be included, because expected or unexpected change of fertility and mortality can also affect to farmers' decisions on breeding and selling. Additionally farmer-specific and animal-specific individual heterogeneity also should be considered to decide on breeding and selling the animals.

(a) Genetic And Biological Aspect

i. Fertility and Mortality

In crop farm, since farmers also consider agronomic constraints such as fertilizer management and pest control, farmers should follow land rotation rules, in consequence, the output can be zero regardless of profitability.[6] Contrary to crop farmers, the animal farmers do not have any land rotation issue, but genetic and biological issues are more relevant as mentioned. In terms of fertility and mortality, Gonzales et al(2004) included fertility cost in a bioeconomic model to consider the number of doses of semen, hormonal treatments, etc, and elaborated the profit function to estimate fertility cost and profit.[22] The breed improvement program to increase animal productivity is largely sutudied in sub-sahara africa where has severe constraints on animal production, [23] and the genetic and economic responses over multiple generations were calculated considering a quadratic profit function combining protein yield and days open.[24]. In terms of carbon reduction, improvements in animal productivity, intensification of production and fertility can reduce GHG emissions/kg product.**(author?)** [25]

The research about fertility of animal is focused to the relationship between the fertility improving effort as represented the veterinary cost and productivity as represented the meat supply to market. In this model, the total size of herd is used for proxy for fertility and mortality, because the change of the fertility and mortality primarily influences to total size of herd, which is regarded as asset to farmers. Generally the fertility is calculated a number of new born divided by inseminated cow and mortality is calculated by difference of animal inventory, but the limit of data availability, The herd size is computed by the sum of all breeding and selling animals.

$$d^*{}_{iat} = Z_{iat}\delta_a + \psi_{iat} \tag{11}$$

$$\Rightarrow d^*{}_{iat} = S_{iat}\pi_a + \tilde{Z}_{iat}\gamma_a + \omega_{iat} \tag{12}$$

Z_{iat}: a vector of possibly common variables with outcome equation ($\tilde{Z}_{iat}$) + a total size of the herd (S_{iat})

S_{iat}= (s_{i1t-1},s_{i2t-1},...,$s_{i,A-1t-1}$), s_{i1t-1}= a number of each type of animal at t-1

If S_{iat} is increased, it can be interpreted by fertility rate become high and mortality rate become low.

ii. Individual Heterogeneity with Panel Data

The above described sample selection model is fitted to rather cross-sectional data than panel. With panel data, the error terms in outcome equations and selection equation is not assumed IID because the property of panel data. The animal farmer also has unique property to breed the animals to select feeding type, fertilizer using or selling animal to make data be censored or move. Either unobserved factors are economical or non-economical, unobserved farmer and aniaml specific individual characteristics may be related to explanatory variables in a selection equations, the different breeding purpose of each type of animal is also included in these unobserved factor. Therefore, sample selection model with panel data is denoted as following.

$$y^*{}_{iat} = X_{iat}B_a + \alpha_{ia} + \varepsilon_{iat} \tag{13}$$

$$d^*{}_{iat} = S_{iat}\pi_a + \tilde{Z}_{iat}\gamma_a + \eta_{ia} + \mu_{iat} \tag{14}$$

where,α_{ia},η_{ia}mean farmer & animal specific individual effects, and error terms of outcome and selection equations (ε_{iat} andμ_{iat}) is IID under the assumption as$\alpha_{ia}$is uncorrelated withε_{iat} and$\eta_{ia}$is uncorrelated withμ_{iat} .$y^*{}_{iat}$is a latent variable corresponding output whenever the latent variable of selection equation ($d^*{}_{iat}$) is above zero and zero otherwise.

The denotationη_{ia} is farmer and animal specific individual effect which is a non-conditional factors to breed/sell animals and to demand input elements. However, if unobserved effectsη_{ia} is correlated with the explanatory variables $Z_{iat}(= S_{iat}\pi_a + \tilde{Z}_{iat}\gamma_a\ )$, the estimated coefficient can be biased. There are many applications the point of introducing the unobserved effect is to allow unobservable variables to be correlated with some elements of explanatory variables. Chamberlain's method allowed for correlation between η_{ia}andZ_{iat} by assuming a conditional normal distribution with linear expectation and constant variance. Mundlak(1978) approach would add the average value of the explanatory variables and assume that coefficients are constant across time. Then, the parameters can be estimated by pooled probit. If the endogenous explanatory variable has a conditional normal distribution, the individual effect can be re-written as η_{ia}=$\bar{S}_{ia}\lambda_a$+$\bar{\tilde{Z}}_{ia}\lambda_{2a}$+$\nu_{ia}$ by Chamberlain's method. It follows a reduced from probit,

$$y^*{}_{iat} = 1[S_{iat}\pi_a + \tilde{Z}_{iat}\gamma_a + \bar{S}_{ia}\lambda_a + \bar{\tilde{Z}}_{ia}\lambda_{2a} + \nu_{ia} + \mu_{iat} > 0] \tag{15}$$

Table 1: The selling and breeding average

		male calf	cow	sheep
sheep farm	Sell	4.12%	2.67%	92.91%
	Breed	3.16%	10.65%	84.72%
		female calf	male calf	cow
cattle farm	Sell	5.35%	54.15%	40.50%
	Breed	10.14%	24.65%	65.21%

The equation(15) can re-write by combining error terms $\kappa_{iat} = \nu_{ia} + \mu_{iat}$ as $y^*{}_{iat} = 1[S_{iat}\pi_a + \tilde{Z}_{iat}\gamma_a + \bar{S}_{ia}\lambda_a + \bar{\tilde{Z}}_{ia}\lambda_{2a} + \kappa_{iat} \geq 0]$, where $y^*{}_{iat}$ is the endogenous explanatory variable, ci1 is the unobserved heterogeneity. in this paper, a theory of Chamberlain is applied

$$d^*{}_{iat} = S_{iat}\pi_a + \tilde{Z}_{iat}\gamma_a + \bar{S}_{ia}\lambda_a + \bar{\tilde{Z}}_{ia}\lambda_{2a} + \kappa_{iat} \tag{16}$$

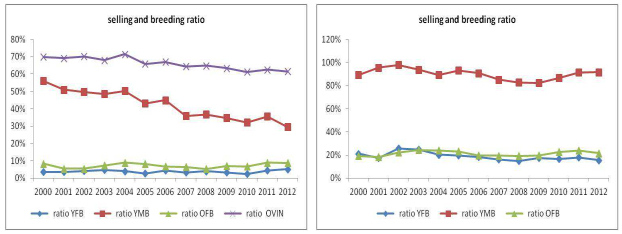
$$\eta_{iat} = \bar{S}_{ia}\lambda_a + \bar{\tilde{Z}}_{ia}\lambda_{2a}, \kappa_{iat} = \nu_{ia} + \mu_{iat} \tag{17}$$

$$Z_{iat}\delta_a = S_{iat}\pi_a + \tilde{Z}_{iat}\gamma_a, \bar{Z}_{iat} = \bar{S}_{ia}\lambda_a + \bar{\tilde{Z}}_{ia}\lambda_{2a} \tag{18}$$

Especially interesting from the point of view, the animal breeding is not the only one purpose to sell itself. In the crop farm, if farmers allocate a land to plant one type of crop, it automatically means a farmer will harvest those crops and will sell to market or consume by themselves. It means if latent variable of land allocation is positive, latent value of selling quantity is automatically determined under no unexpected exceptional shock such as climate disaster. But animal farms have a different situation. The breeding is not automatically related to selling because the purpose of breeding animals is heterogeneous across all types of animals.
As presented in <Table 1>

The average ratio of three type of animal on selling and breeding of two farm categories is presented in <Table 1>. Some types of animal are not included because the share is little. In terms of sepply in sheep farm, the sheep meat dominates the total supply of sheep farm as around 93%, and male calf has around 4%, and other cattles get remains. Since female calf,

Figure 1: Selling and breeding ratio



(a) Sheep farm (b) Beef cattle farm

bull and dairy cow is rarely provided from sheep farm, these two types of animal is excluded. As expected, the share of breeding is higher than the share of supply in cow, and just opposite condition in male calf. It supports the basic idea as farmers breed female cattle to get male calf to provide meat market. In the beef cattle farm, same situation is confirmed. the The cow and male calf are mainly provided to the beef market, but the farmers breed cow more than male calf. It means also that the breeding purpose is different from cow and male calf. The data of sheep, bull and dairy cow is also excluded because of rare breeding.

<figure 1> present the percentage of selling quantity from breeding quantity. Normally 70% of breeding sheep is provided to market in sheep farm, and over 80% of male calf is provided to beef market with maintaining breeding numbers of animals by reproduction. However, the selling and breeding ratio of female cattle even if young or old are low.

iii. Endogeneity Check

Even though the heterogeneity problems are resolved by following Chamberlain's method, the endogeneity between$S_{iat}$and κ_{iat} is still remained. Therefore, any test for selection bias should be tested to check the correlation. Nijman and Verbeek(1992) proposed a simple test as add the lagged selection indicator to equation and do t-test for the significance. If $S_{iat}$and κ_{iat} are not correlated selection in the previous time, the selection in previous year does not affect to the selection at present year. If $S_{iat}$is correlated to κ_{iat}, Instrument probit should be used, the lagged price and subsidy can be the instruments for s S_{iat}. [26]

(b) Heckman 2 Step Method (Heckit)

From the asymptotic efficiency, MLE is the best way to estimate coefficient with censoring samples. However, 2step Heckit instead of MLE is more popular because it need simpler computation technique.**[27]** The proposed a two-step estimation procedure using the Inverse Mills Ratio(IMR) to take account of the selection bias. This idea demonstrates Heckman's insight that sample selection can be viewed as a form of omitted-variables bias, as conditional on both explanatory variables and IMR. If IMR is significant, it is interpreted that the corner solution raised the sample selection bais. The corner solutions induce the sample selection problem caused by the self selection by the individuals or data units being investigated and by sample selection decisions by analysts or data processors operate.[7]. Heckmas's 2 step method is a alternative to overcome the misspecification through the inclusion of a correction term that account E(ε_{iat} $|Z_{iat}$,${d^*}_{iat}$=1). Theoretically the estimation E($y_{iat}|X_{iat}$,${d^*}_{iat}$=1) is equal to $X_i\beta_i$ +E(ε_{iat} $|Z_{iat}\beta_a$,μ_{iat}) = $X_{iat}\beta_a$ +E($\varepsilon_{iat}|\mu_{iat}$) = $Z_{iat}\delta_a$ $+\theta_i\mu_i$. If $\theta_i$andμ_i are uncorrelated, E($y_i|X_i$,${d^*}_{iat}$=1) =$X_i\beta_i$, it means no difference raised from selection andδ_a is consistently estimated by OLS. However, if $\theta_1$is not zero, E($y_i|X_i$,${d^*}_{iat}$=1) = $X_{iat}\delta_a$ $+\theta_i\mu_i$. Sincey_i=1 on selected sample, E($y_i|X_i$,${d^*}_{iat}$=1) =$X_i\beta_i$ $+\theta_i\frac{\phi}{\Phi}(X_i\beta_i)$ .This $\frac{\phi}{\Phi}$ term is "Inverse Mills Ratio" which means the ratio of the probability density function to the cumulative distribution function of a distribution.. If$\theta_i\frac{\phi}{\Phi}(X_i\beta_i) \neq 0$, it means selection bias can be viewed as an omitted variable problem in the selected sample. In livestock farm modeling, the equation is converted as following. E($y_{iat}|X_{iat}$,${d^*}_{iat}$>1) = $X_{iat}\beta_a$+ $\theta_i\frac{\phi}{\Phi}(X_i\beta_i)$. where θ_i is covariance between error terms. If the objective functions are significantly different coefficient whether include inverse mills ratio or not, the existence of sample selection bias detected. In other words, if Inverse Mills Ratio is significant in outcome equation, it means that the participation behavior effect to amount decision.

so final selection equation is constituted like following: ${d^*}_{iat}$=$Z_{iat}\delta_a$+ $\bar{Z}_{ia}\lambda_a$ $+\kappa_{iat}$ with conditional expectation is

$$E(y_{iat}|X_{iat}, \alpha_{ia}, {d^*}_{iat} > 0) = X_{iat}\beta_a + \alpha_{ia} + \frac{\sigma_{\varepsilon\kappa,at}}{\sigma_{\kappa,at}} \times \frac{\phi[(Z_{iat}\delta_a + \bar{Z}_{ia}\lambda_a)/\sigma_{\kappa,at}]}{\Phi[(Z_{iat}\delta_a + \bar{Z}_{ia}\lambda_a)/\sigma_{\kappa,at}]} \tag{19}$$

And ${d^*}_{iat}$>0 can be re-written as $\Phi\left[\frac{Z_{iat}\delta_a+\bar{Z}_{ia}\lambda_a}{\sigma_{\kappa,at}}\right] = \Phi_{at}(Z_{iat}\delta_a+\bar{Z}_{ia}\lambda_a)$ by definition of MLE function. In summary, the explanatory variables are output prices, subsidy and input prices in outcome equation, and tthe average of the explanatory variables in outcome equation and total size of herd are added in selection equation to consider biological aspect and individual unobserved heterogeneity.

Table 2: Relation between amount of breeding

Sheep farm

	$U_{malecalf}$	$U_{malecalf}$	U_{sheep}
$U_{malecalf}$	1	0.80	-0.22
$U_{malecalf}$		1	-0.43
U_{sheep}			1

Beef cattle farm

	$U_{femalecalf}$	$U_{malecalf}$	U_{cow}
$U_{femalecalf}$	1	0.86	0.92
$U_{malecalf}$		1	0.96
U_{cow}			1

(c) Multivariated Selection Rule

The Heckit model is fine in single output profit function because it is based on single selection rule. But livestock farmers provide the multi-outputs after deciding how much to breed and how much to sell. As discussed in Catsiapis and Robinson, in scholarship programs, the 'round-one' selection will occur when applicants apply to join the program, and the 'round-two' selection will occur when program organizer make choice for the program participants. [28]. In scholarship program case, the estimation based on single selection rule may ignore the correlation between rounds. It means that the outcome of a type of animal can be influenced by other animals breeding. For example, In animal farm, the single selection rule is fine for farmers who breed only one type of animal and sell only one type of animal. But many farmers breed several types of animal. If the desicions on breeding and selling animal of animal is related to another kind of animal, the estimates of outcome equation with heckit can be biased. It means Inverse Mills ratio of all type of animal should be included for each profit function to estimate unbiased coefficient. Since the animal is a living creature to reproduce and grow up, young calf in last year become to old cow which can reproduce. It means if farmers sell cow more to meat market to respond to the increased market price of old female, he get new young cattle less,and the amount of cow is decided by a number of young female calf in last years. As presented <Table 2>

he strongest relation is $U_{malecalf}$ and U_{cow} in two farm type and $U_{femalecalf}$ and U_{cow},too. Of course, the relationship between cattle and sheep is negative as substitution property.

Moreover, the number of animal cannot be dramatically changed compared to crop farm. Accordingly, the change of animal type is respectively more reluctant than crop change. The land use for crop seems to be newly set at spring time, and farmer allocate to plant crop to their relatively empty land. The animal farmers, however, should rely on quasi fixed animal asset which he cannot get or destroy easily, the animal farmers are more limited to change the composition of output quantity. To maximize profit across time, the relation between different type of animal across time should be considered.

$$E(y_{iat}|X_{iat}, {d^*}_{i1t} > 0, {d^*}_{i2t} > 0, ..., {d^*}_{iAt} > 0)$$

$$= E(y_{iat}|\kappa_{i1t} > -\tilde{Z}_{i1t}\delta_1 - \bar{Z}_{i1}\lambda_1, ..., \kappa_{iAt} > -\tilde{Z}_{iAt}\delta_A - \bar{Z}_{iA}\lambda_A)$$
$$= (y_{iat}|X_{iat}, \alpha_{ia}, |\kappa_{i1t} > -\tilde{Z}_{i1t}\delta_1 - \bar{Z}_{i1}\lambda_1, ..., \kappa_{iAt} > -\tilde{Z}_{iAt}\delta_A - \bar{Z}_{iA}\lambda_A) \quad (20)$$

(d) Other Issues

i. Endogeneity Assumption

To estimate unbiased coefficient, sample selection model should be examined by multivariate selection rule with considering lagged number of each type of animals for breeding and selling. Since the description of Heckit model as above is based on cross-sectional data, there are more consideration to eliminate the correlation to apply Heckit model to panel data.

First is

$$E(\kappa_{iat}\kappa_{ia't}|Z_{iat}, Z_{ia't}) = 0 \quad (21)$$

Second is

$$E(\kappa_{iat}\kappa_{iat'}|Z_{iat}, Z_{iat'}) = 0 \quad (22)$$

The meaning of first equation(21) is the remaining error is not correlated with error terms in another selection equation, and implies that profitability at the same time in not correlated across animal types. The meaning of second equation(22) is that error term of outcome equation at time t should not correlated the error term of selection equation at time t'. It implies that random shock profitability will not affect future keeping and selling animals.

ii. Unbalanced Panel

Additional problem is about data set. The data from Farm Accountancy Data Network (FADN) is used for analysis in this paper.[4] FADN data is a

[4]FADN is an instrument for evaluating the income of agricultural holdings and the impacts of the Common Agricultural Policy and The services responsible in the Union for the operation of the FADN collect every year accountancy data from a sample of the agricultural holdings in the European Union. Derived from national surveys, the FADN is the only source of microeconomic data that is harmonized[29],

typically unbalanced panel because the data is repeated for some farms but some farms may not enter in every year. In this case, the Error Correction Model on which panel-data technique relies should be generalized to the unbalanced panel. Therefore, to deal with unbalanced panel, theoretically following assumption is needed

$$\hat{\beta} = \left(N^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \mathrm{s}_{it} \ddot{x}_{it} \ddot{x'}_{it} \right)^{-1} \left(N^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \mathrm{s}_{it} \ddot{x'}_{it} \ddot{y}_{it} \right)$$

$$= \beta \left(N^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \mathrm{s}_{it} \ddot{x}_{it} \ddot{x'}_{it} \right)^{-1} \left(N^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \mathrm{s}_{it} \ddot{x'}_{it} u_{it} \right) \tag{23}$$

where define

$\ddot{x_{it}} = x_{it} - T_i^{-1} \sum_{t=1}^{T} \mathrm{s}_{ir} x_{ir}$, $\ddot{y_{it}} = y_{it} - T_i^{-1} \sum_{t=1}^{T} \mathrm{s}_{ir} y_{ir}$, and $T_i = \sum_{t=1}^{T} \mathrm{s}_{it}$

This assumption ensure consistency if fixed effect on the unbalanced panel.[26] To deal with unbalanced panel with FADN, Platoni et al.(2012) proposed two-stage procedure for censored data to account for heteroscedasticity and correlation of the error terms of the first-stage probit model.[30]

In summary, the estimation methodology is basically following Heckman 2 step estimation. Firstly, the selection model of keeping and selling animals is estimated by Probit with selection indicators as the herd size, the average value of explanatory variables to consider fertility/mortality and individual heterogeneity, relatively. Secondly, estimate outcome equations by SURE method to impose symmetry and homogeneity property of profit function. To compare the difference of the results by applying different selection rules, estimate differently with three selection rules. First, the single selection rule by Heckit model. Second, the multivariate selection rule within same outcome group. It means that the IMRs derived from $Q_a$are added to only outcome equations of Q_a,but not added to the outcome equation of U_a. In the case, only the effect of breeding behavior of one type of animal on breeding type of other type of animal and the effect of selling behavior of one type of animal on selling type of other type of animal are considered. Last, apply the multivariate selection rule to all outcome equations. In third case, all breeding and selling behavior of one type of animal are considered to other animal's breeding and selling activities.

Table 3: the number of corner solutions

Sheep		Beef cattle	
variables	numbers	variables	numbers
sample(N)	4,431	sample(N)	8,692
Q_{sheep}	188	$Q_{femalecalf}$	5,168
$Q_{malecalf}$	2,908	$Q_{malecalf}$	102
Q_{cow}	3,283	Q_{cow}	463
U_{sheep}	0	$U_{femalecalf}$	324
$U_{malecalf}$	2,808	$U_{malecalf}$	0
U_{cow}	2,811	U_{cow}	125

4. DATA Description & Statistic Notation

(a) Samples

In France, the animal farm are mainly categorized to 4 sectors as "Dairy farm", "Beef cattle", "Mixed cattle" and "Sheep" by OTEX standard(orientation technico-economique). [5] Every farms in 4 categories have the different main products as milk, beef, milk&beef and sheep meat. To simplify the model,"Beef cattle" and "Sheep" are analyzed to only deal with meat market except milk or other sub-products(wool, cheese). All farmers in 2 categories breed one or more animal such as asset and decide to sell their animal for meat market in any time in a year. The samples are around average 380 individual farmers of sheep category and about 580 farms of beef cattle category during the period 2000~2012. Data cover all region of France, and can be integrated to regional level, but it is not possible to integrate to department or district level. All farmers breed main animals(sheep and male calf) and optionally sub-animals. Even if some farmers also have arable crop in a small fraction of land, all crops from livestock farm are assumed to self-consume without selling.

(b) Variables

i. Breeding numbers(U_a) and selling numbers (Q_a)

To detect the different response across different type of animal, all animals are categorized by age and sex in a species; young & old female, young and old male for cattle and sheep. In FADN, total 14 kinds of cattle and 4 kinds of sheep information is provided

Cattle can be divided by 4 types (young male cattle, young female cattle, old

[5] In French, "Bovin Laitiere", "Bovin viande","Bovin mixed" and "Ovin"

Table 4: categorization of cattle

category	Male	Female
calf	young veaux de batterie hors integration, autres veaux de batterie hors integration, veaux de boucherie en integration, broutards, autres bovins de moins de 1 an, veaux de 8 jour remettre, bovins meres de 1-2 ans maigres, bovins meres de 1-2 ans gras	genisses de 1-2 ans
Bulls, Cow	old taureaux (>2ans), autres bovins meres (>2ans)	genisses d'elevage (>2ans), genisses viande (>2ans),

male cattle, old female cattle), however, sheep is merged in one type because of the limit of FADN data. A farm can choose to breed sheep or cattle regardless of farm categorization, a farm in "beef cattle" and "sheep" can breed maximum 8 types of animal(4 types of cattle and sheep). To compare directly between different type of animals, the number of head of each animal type is converted to LU(Livestock Unit). It is helpful to compare revenue or cost across animals and to set allocation rule to different types. Based on the coefficient of LU of old cattle is 1, the coefficient of young cattle are 0.30~0.75 and of sheep is 0.05~0.15.

(c) Output price and subsidy (p$_a$ and r_a)

The selling prices and subsidy data for all types of animals at each farm are provided in FADN. It is fine to get farm-level price data, but on the contrary it means also if a farmer do not sell animal, the price data and subsidy is missing. Therefore, the regional average price is supplemented to missing data. By the FADN, all farmers get 15 kind of subsidy from inter-national, national or regional level. In terms of subsidy, some subsidy is given based on animal, other subsidies are given based on land. For example, "aides aux jachere" is based on land, "prime ovines et caprins" is based on animals. The subsides based on animal are re-distributed by animal-specific for each type of animal and subsidies based on land is considered to negative rent.

(d) Input price and quantity (x$_k$ and w_k)

Table 5: Data description

Beef cattle		Sheep	
variables	mean	variables	mean
$Q_{femalecalf}$	2.317	Q_{sheep}	57.71
$Q_{malecalf}$	24.128	$Q_{malecalf}$	2.57
Q_{cow}	17.928	Q_{cow}	1.66
$U_{femalecalf}$	13.08	U_{sheep}	80.50
$U_{malecalf}$	32.03	$U_{malecalf}$	3.01
U_{cow}	84.26	U_{cow}	10.10
$P_{femalecalf}$	1519.67	P_{sheep}	400.19
$P_{malecalf}$	1944.5	$P_{malecalf}$	1792.2
P_{cow}	2562.8	P_{cow}	2602.04
$subsidy_{femalecalf}$	225	$subsidy_{sheep}$	376.4
$subsidy_{malecalf}$	301	$subsidy_{malecalf}$	312.8
$subsidy_{cow}$	401	$subsidy_{cow}$	354.8
size of herd	171.44	size of herd	155.58

To breed animals, farmers need a lot of inputs such as feeds, fertilizers, energy and supporting equipment & buildings, etc. All inputs are categorized by 3 groups as concentrate feed, fertilizer and others. The purpose of this categorization is to analyst the causality between inputs and GHG emission because CH_4 emission is related to "concentrate feeds" by enteric fermentation and manure management, N_2O emission is related to "fertilizer". Even though CO_2 is also emitted in animal farm, it is excluded because the share is too small. The prices and quantities of concentrate feeds are specific to each animal and the prices and quantities of other inputs are aggregated. However, since FADN only provides inputs cost, the input prices are supplemented with national-level prices from EUROSTAT by index from based on 2000yr. To get Input quantity, firstly convert input price to tornqvist price with cost data and secondly indexing input cost based on 2000yr, and finally compute input quantity index with cost index and price index. [31]

To summary, with 5 kinds of animal in beef cattle and sheep farm, the data of selling & buying prices and quantities of animal, subsidy rate/LU and input cost/farmer come from RICA, input prices come from EUROSTAT and compute input quantity dividing cost by tonqvist price. In sheep farm, Total number of farm is slightly increased during last 10 years. (325→384 on annual average), and also average land is also increase except 2005-2006 season, according to farm increasing. Therefore, average number of breeding animals based on LU is relatively stable during considering period. But, beef cattle farm has different pattern against sheep farm, total number of farms are increased about 20% during last 10 years. (597→718 on annual average) like sheep farm. however, Land per farm in cattle is much lower than land per farm in sheep farm as long as LU pattern is similarly stable. It means that farmers for beef apply the intensive farming contrary to sheep farmer apply grazing. In sheep farm, the biggest sheep meat production region is Midi-Pyrenees, which has quarter of total number of animal in sheep farm is followed by PoitouCharentes(12%), PACA(10%), Limousin, Corse and Aquitaine(each 8%). This ratio is almost same during 13years. For beef cattle farm, Limousin is the region to provide the most, and followed by Auvergne, Bourgogne, etc. The regional difference of two animals is caused by geographical aspect or soil quality. Financially, the profitability in sheep farm is becoming worse. Although gross production per farm is increased about 22% during 13years, cost is increased more than double(143%) during same time. The financial condition of beef cattle farm is more severe, cost per farm became more than gross product after 2004.

5. Empirical Results

The multivariate selection rule is empirically applied to beef cattle and sheep market. Firstly note, all regression on panel data is based on pooling method because of technical limit. Firstly, compare the own price elasticity across different 3 selection rule; first is single selection rule, second is multivariate selection rule within same output function group (output function for sale and output function for breeding), third is multivariate selection rules to all output function. The corner solution in input demand function is not considered.

(a) Sheep Farm

As presented <Table 6>, the price elasticity of sheep sale becomes more elastistic when multivariate selection rule is applied than single selection rule. It means the sheep meat sale is influenced by the choice to breed and sell sheep and beef cattle. The elasticity of male calf become also more elastistic under multivariate selection rule, but the sheep sale does not affect to the sale of male calf. The elasticity of cow is significant under multivairate selection rule, but near to zero. It means the sales of cow do not depend on prices. The choice of breeding is different to the choice of sale. The sheep breeding becomes to less elastistic when multivariate selection rule is applied. It means that the choice of breeding and selling beef cattle in sheep farm make the choice of sheep breeding be less sensitive to subsidy. If policy maker intend to reduce total number of sheep though subsidy cut, the effect is less effective when the choice of cattle breeding and selling is included. The elasticity of male calf and cow are also influenced by the choices of breeding and selling of other types of animal, they also become near to zero.

Table 6: Comparison between selection rules: sheep farm

	Selling				Breeding			
	Animal type	SS	within MS	global MS	Breeding	SS	within MS	global MS
Own-Price Elasticity		4.877***	3.644***	5.656***		7.909***	5.487***	5.554***
IMR of Q_{sheep}		-55.49***	-71.616***	-178.17***				-180.81***
IMR of $Q_{malecalf}$			48.187***	-21.97**				-23.27***
IMR of Q_{cow}	Q_{sheep}		-30.986***	-110.61***	U_{sheep}			-137.26***
IMR of $U_{malecalf}$				280.65***			-111.644***	276.07***
IMR of U_{cow}				-75.47***			1467.435***	-53.74***
Own-Price Elasticity		0.245***	0.565***	0.795***		0.062***	0.037*	0.058***
IMR of Q_{sheep}			0.389	-1.021				-14.959***
IMR of $Q_{malecalf}$		-0.145	-2.432***	-14.056***				-9.710***
IMR of Q_{cow}	$Q_{malecalf}$		2.766***	-7.047***	$U_{malecalf}$			-9.043***
IMR of $U_{malecalf}$				11.239***		0.933***	-7.902***	19.612***
IMR of U_{cow}				5.841***			7.654***	9.677***
Own-Price Elasticity		-0.006***	-0.004	-0.005**		0.012***	0.002	0.028***
IMR of Q_{sheep}			0.958***	-5.610*				2.025
IMR of $Q_{malecalf}$			-1.915***	-8.074***				-22.56***
IMR of Q_{cow}	Q_{cow}	0.219	2.408***	-4.753***	U_{cow}			-21.49***
IMR of $U_{malecalf}$				11.221***			-5.897	13.42*
IMR of U_{cow}				4.201***		-1.394***	0.851	4.196*

parameter significant 1% : ***, 5%: **, 10%: *
SS: single selection rule, Within MS: Multivariate Selection rule with in same output function category, Global MS: Multivariate function with all output function

The one distinguishable thing is the sale of sheep affects to the breeding decision of male calf, but does not affect to the breeding decision of cow.

(b) Beef Cattle Farm

As presented <Table 7>, in terms of selling beef of female calf, the price elasticity is negatively related to market price. When the multivariate selection rule with selling quantity of other type of animal is applied the elasticity of female calf become significant and more elastistic. For selling of male calf, the selection of selling male calf and breeding of female calf and cow affect to the selling choice of male calf, but the price elasticity is not significant. In terms of selling of cow, sample selection bias is driven by selling of male calf and breeding of all type of animal. The price elasticity of cow becomes more elastistic, when multivariate selection rule is considered. The subsidy elasticity on breeding is relatively more inelastic than price elasticity on selling. Especially, the elasticity of female calf and cow become insignificant when multivariate selection rule is applied. the elasticity of breeding calf is not affected from selection issues from female calf,

Table 7: Comparison between selection rules: Beef cattle farm

	Selling				Breeding			
	Animal type	SS	within MS	global MS	Animal type	SS	within MS	global MS
Own-Price Elasticity		-0.022	-0.025	-0.043*		0.091***	0.085***	0.004
IMR of $Q_{femalecalf}$		-0.320	0.152	-5.016***				-5.561
IMR of $Q_{malecalf}$	$Q_{femalecalf}$		0.257	2.932***	$U_{femalecalf}$			14.244***
IMR of Q_{cow}			0.038	-1.254				-6.800**
IMR of $U_{femalecalf}$				3.952***		0.300	16.85***	7.709***
IMR of U_{cow}				-0.775			-12.24***	-7.476***
Own-Price Elasticity		-0.080***	-0.080	-0.055		0.187***	0.177***	0.029***
IMR of $Q_{femalecalf}$			-1.473	-14.513				12.499
IMR of $Q_{malecalf}$	$Q_{malecalf}$	-8.300	-1.543	15.094***	$U_{malecalf}$			32.240***
IMR of Q_{cow}			0.272	-10.022				-15.778**
IMR of $U_{femalecalf}$				18.543***			32.70***	20.518***
IMR of U_{cow}				-14.657***			-24.23***	-22.667***
Own-Price Elasticity		-0.060***	-0.068***	-0.144***		0.254***	0.239***	0.012
IMR of $Q_{femalecalf}$			3.364	-9.918				-4.571**
IMR of $Q_{malecalf}$	Q_{cow}		5.665	18.265***	U_{cow}			64.025***
IMR of Q_{cow}		0.205	0.662	-5.750				-33.29*
IMR of $U_{femalecalf}$				11.093***			81.51***	42.23***
IMR of U_{cow}				-8.433**		0.560*	-58.61***	-21.26**

parameter significant 1% : ***, 5%: **, 10%: *
SS: single selection rule, Within MS: Multivariate Selection rule with in same output function category, Global MS: Multivariate function with all output function

but the elasticity of cow is influenced by it.

(c) The Impact Of Climate Effect To Farm Deceision

A variable “climate dummy” is added to consider climate disaster. In livestock farm, farmers decide own behavior to breed and sell animals depending on expected value under rational expectation of the economy. However, some unexpected shock should be considered because output can be also changed unexpectedly by epidemic or natural disaster. To consider unexpected shock, climate dummy is used for a dummy variable to represent climate disaster like drought

$$y^*{}_{iat} = X_{iat}B_a + \alpha_{ia} + \varepsilon_{iat} + climatedummy \tag{24}$$

$$d^*{}_{iat} = S_{iat}\pi_a + \tilde{Z}_{iat}\gamma_a + \bar{S}_{iat}\lambda_a + \bar{\tilde{Z}}_{iat}\lambda_{2a} + \kappa_{iat} + climatedummy \tag{25}$$

Table 8: The effect of climate disaster

Beef cattle farm	Q_{YFB}	Q_{YMB}	Q_{OFB}	U_{YFB}	U_{YMB}	U_{OFB}
	0.113	-1.664***	1.797***	0.355	0.559	6.979***
Sheep farm	Q_{SHEEP}	Q_{YMB}	Q_{OFB}	U_{SHEEP}	U_{YMB}	U_{OFB}
	16.45***	0.849***	0.817***	16.918***	1.504***	2.545***

parameter significant 1% : ***, 5%: **, 10%: *

The climate dummy set 1 when farmer get the subsidy “Aide directe pour compenser unn accident climatique”, 0, otherwise.

As presented <Table 8>, the effect of climate disaster is positively correlated to the selling and breeding except the male calf in beef cattle farm. All variables are significantly correlated to climate accident in sheep farm, but the breeding of calf is not influenced by climate disaster.

6. Conclusion and Further Consideration

In this paper, the multivariate selection rule to modeling livestock farm is proposed with the normalized quadratic profit function considering the animal breeding. To eliminate sample selection bias and to consider genetic and biological aspects, Heckman 2-step model is applied. The sample selection bias is considered because the unobserved random terms on breeding and selling can be correlated. The fertility and mortality, different breeding purpose of each type of animal and reproduction are considered for the genetic and biological aspects. The size of total herd ia used for the selection indicators to represent the fertility and mortality and the different breeding purpose of animal is also reflected to consider the unobserved individual effect by using the average values of the explanatory variables. The reproduction is the main reason to apply multivariate selection rule. To follow Heckam 2-step model, Probit and Simultaneous Equation Model for panel data are applied. The Inverse Mills Ratio are computed in each Probit selection equation, and added to the outcome equation by different selection rules to compare single selection rule and mutivariate seleciton rule. Even though the estimation is limited to pooling method because of technical limitation, the price elasticity are different by selection rules. Additionally, the effect by climate accident also estimated.

This method can be useful to policy makers to evaluate the environmental program on agriculture, especially carbon reduction program. Since carbon reduction program normally based on economic instrument like tax(carbon tax or energy tax), subsidy (bonus-malus) and market(Emission trading),the estimates obtained from this model in this paper is one of the indicator to know farmers' responses on price changes.

Even though sample selection is applied to get rid of some endogeneity issues, there are still considerable factors to make a biased result. The first thing is spatial issue. The spatial characteristics like soil and climatic condition can be considered importantly. The knowledge of the geographical location of each farm allows to know the present portfolio of activities locally. In other words, agricultural and agri-environmental activities that are present in the physical and social landscape of animal farms. Taking into account this effect generates another form of endogeneity well known, due to spatial autocorrelation. Second thing is auto-correlation. The choice of activity of an operator at time t which depends on own choice at previous time generate an endogeneity problems. It is well known that the integration of series poses serious problems spurious regressions which shows for data aggregated at the regional level the series agricultural prices, use of inputs and outputs are cointegrated, as was to be expected since the quantities of inputs and outputs can hardly away from each other indefinitely.

Finally, in terms of reduction of GHG emission, farmers' response to climate shock is provided in this paper,but the more important thing to policy maker is farmers' responses to GHG reduction policy. To investigate the effect of GHG reduction policy, the direct and indirect effects should be distinguished. The direct effect on each livestock farm can be dealt like an exogenous change in operating conditions. It is for each farm to estimate changes in choice due to some changes in conditions as stated, a change in input prices, or a change in subsidy level. The indirect effects raise the second round via market when all farms react. For example, if tax on certain fertilizers is newly introduced, the input choices are changing as following three situations. First, if the fertilizers become more expensive, farms may carry on a more intensive use of other inputs, and this could induce a change in the price of these inputs or changes in practices that will influence neighboring farms. Second, the activity choices are changing. The intensive activities fertilizer could be replaced by other less intensive fertilizer directly and the less fertilizer reduce the local corn feed supply indirectly.Third, farms can disappear. This induces a downward pressure on land prices, allowing the remaining farms to grow. Another reaction to a tax on fertilizers is extensification operations, reducing margins, which is possible only getting bigger - and therefore an upward pressure on land prices or by reducing profit, possibly offset by diversification.

References

[1] M. LHERM, D.BEBIN, and G.LIENARD. Elevage allaitants charolais des zones herbageres face a la reforme de la pac proposition d'une typologie d'adaptations et premiers resultats 1993. *INRA*, 1994.

[2] Steven T Yen and Biing-Hwan Lin. A sample selection approach to censored demand systems. *American Journal of Agricultural Economics*, 88(3):742–749, 2006.

[3] Sungno Niggol Seo and Robert Mendelsohn. Climate change adaptation in africa: a microeconomic analysis of livestock choice. 2007.

[4] Félix Goyache, Juan P Gutiérrez, Isabel Álvarez, Itziar Fernández, LJ Royo, and E Gómez. Genetic analysis of calf survival at different preweaning ages in beef cattle. *Livestock production science*, 83(1):13–20, 2003.

[5] John M Marsh. Impacts of declining us retail beef demand on farm-level beef prices and production. *American Journal of Agricultural Economics*, 85(4):902–913, 2003.

[6] Anne Lacroix and Alban Thomas. Estimating the environmental impact of land and production decisions with multivariate selection rules and panel data. *American Journal of Agricultural Economics*, 93(3):784–802, 2011.

[7] James J Heckman. Sample selection bias as a specification error. *Econometrica: Journal of the econometric society*, pages 153–161, 1979.

[8] Bert Metz. *Climate Change 2007-Mitigation of climate change: Working Group III Contribution to the fourth assessment report of the IPCC*, volume 4. Cambridge University Press, 2007.

[9] INRA. How can french agriculture contribute to reducing greenhouse gas emissions? 2013.

[10] Stéphane De Cara, Martin Houzé, and Pierre-Alain Jayet. Methane and nitrous oxide emissions from agriculture in the eu: A spatial assessment of sources and abatement costs. *Environmental and Resource Economics*, 32(4):551–583, 2005.

[11] Jelle Bruinsma. *World agriculture: towards 2015/2030: an FAO perspective*. Earthscan, 2003.

[12] Tara Garnett. Livestock-related greenhouse gas emissions: impacts and options for policy makers. *environmental science & policy*, 12(4):491–503, 2009.

[13] PJ Gerber, H Steinfeld, B Henderson, A Mottet, C Opio, J Dijkman, A Falcucci, G Tempio, et al. *Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities.* Food and Agriculture Organization of the United Nations (FAO), 2013.

[14] M. Benoit and H. Dakpo. Greenhouse gases emissions and energy consumption in french sheep for meat farms analysis over the period 1987-2010. 2012.

[15] p. Veysset, M. Lherm, D. Bebin, M. Roulenc, and M. Benoit. Variability in greenhouse gas emissions, fossil energy consumptionand farm economics in suckler beef production in 59 french farms. *Agriculture, Ecosystems and Environment*, 2014.

[16] M. Doreau and J Dolle. Strategies for reducing greenhouse gas emissions in dairy production-a european perspective. *Eastern nutrition conference (p. 57-77).Presented at Eastern nutrition conference, Montr?al, Canada (2011-04-12 - 2011-04-13).*, 2011.

[17] Richard E Just and Rulon D Pope. The agricultural producer: theory and statistical measurement. 2001.

[18] Rolf Fare, Carlos Martins-Filho, and Michael Vardanyan. On functional form representation of multi-output production technologies. *Journal of Productivity Analysis*, 33(2):81–96, 2010.

[19] A Colin Cameron and Pravin K Trivedi. *Microeconometrics: methods and applications*. Cambridge university press, 2005.

[20] Steven T Yen. A multivariate sample-selection model: estimating cigarette and alcohol demands with zero observations. *American Journal of Agricultural Economics*, 87(2):453–466, 2005.

[21] Francis Vella. Estimating models with sample selection bias: A survey. *Journal of Human Resources*, 33(1), 1998.

[22] O Gonzalez-Recio, MA Perez-Cabal, and R Alenda. Economic value of female fertility and its relationship with profit in spanish dairy cattle. *Journal of dairy science*, 87(9):3053–3061, 2004.

[23] Emily Awuor Ouma and Awudu Abdulai. Contribution of economics to design of sustainable cattle breeding programs in eastern africa: A choice experiment approach. In *2006 Annual Meeting, August 12-18, 2006, Queensland, Australia*, number 25587. International Association of Agricultural Economists, 2006.

[24] AF Groen, AR Vollema, EW Brascamp, et al. A comparison of alternative index procedures for multiple generation selection on non-linear profit. *Animal Production*, 59(01):1–9, 1994.

[25] P Crosson, L Shalloo, D OąŕBrien, GJ Lanigan, PA Foley, TM Boland, and DA Kenny. A review of whole farm systems models of greenhouse gas emissions from beef and dairy cattle production systems. *Animal Feed Science and Technology*, 166:29–45, 2011.

[26] Jeffrey M Wooldridge. *Econometric analysis of cross section and panel data*. MIT press, 2010.

[27] Russell Davidson and James G MacKinnon. *Econometric theory and methods*, volume 5. Oxford University Press New York, 2004.

[28] George Catsiapis and Chris Robinson. Sample selection bias with multiple selection rules: an application to student aid grants. *Journal of Econometrics*, 18(3):351–368, 1982.

[29] FADN. *Farm Accounting Data Network An A to Z of methodology*, 2010.

[30] Silvia Platoni, Paolo Sckokai, and Daniele Moro. Panel data estimation techniques and farm-level data models. *American Journal of Agricultural Economics*, 94(5):1202–1217, 2012.

[31] Rembert De Blander and Bruno Henry de Frahan. Guidelines for estimation and ex-post evaluation using flexible cost functions with eu-fadn and eurostat data. 2011.